Marine Use of Gas Turbines

Keynote Address

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Ladies, Gentlemen

Firstly, I would like to thank the Applied Vehicle Technology Panel organising committee of this symposium for the opportunity of addressing you this morning. I am very conscious of the fact that such a symposium attracts many leading scientists, engineers and academics in the fields that are the subject matter of the event. In such company, and recognising the content of some of the papers due to be presented over the next 4 days, it would be foolish of me to attempt to discuss the technical detail and challenges associated with the process of extending engine life. However, I am the Head of the Group within the United Kingdom Ministry of Defence that is responsible for in-service support of marine propulsion equipments and I feel that I have some credibility in discussing the use of marine gas turbines, the strategic issues that impact on their in-service support and the environment within which they operate. This environment will be a familiar one to many here - one that demands high standards of reliability and availability whilst at the same time being subject to substantial pressures to drive down the overall cost of ownership of these expensive equipments. There are, of course, many elements that contribute to the life cycle costs, some of which I will touch on this morning and others that will be the subject of presentations later in the seminar.

This invitation offers me the opportunity of giving you a short insight into how the Royal Navy has developed marine gas turbines over the last 50 years and how their use has been developed up to the present day including a comparison of the requirements of marine and aero gas turbine engines. I will discuss some of the characteristics of the marine support environment and the strategy adopted by the Royal Navy to take marine propulsion forward into the 21st century.

In order to set the scene, I would like to spend just a few minutes summarising how the Royal Navy arrived at where we are today with every modern major surface warship powered by gas turbine engines.

The middle of the 19th century saw a significant move away from combined sail and steam propulsion of warships to wholly mechanically propelled vessels driven by steam powered reciprocating engines. However, at the dawn of the new century a new technology burst upon the scene. Queen Victoria's Royal Navy fleet review in 1897 saw a steam turbine driven yacht – TURBINA – demonstrate unmatchable performance before the astonished Naval Authorities of the day who had shown little

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interest in the technology before that time. It marked the start of a new era of steam turbine powered ships that was to last well into the second half of the 20th century. Steam turbines were introduced into service remarkably quickly which is in marked contrast to the next marine propulsion revolution – gas turbine propulsion.

The first experimental marine gas turbine went to sea in 1947 and the world's first warship to rely entirely on gas turbine propulsive power was HMS Grey Goose, which was commissioned in 1953. Impressive though the engine was, it was large and very complex and sophisticated for its time being intercooled and recuperated. It was realised that what was needed was a ship propulsion arrangement using a simple cycle solution which had good space and weight characteristics and reasonable lower ship speed efficiency. This could be achieved either by running sided engines or using cruise diesels. I have to say here that I recognise that the diesel engine was also developed, with significant strides made between the two world wars and this generic equipment to this day plays a major role in the propulsion of many of the navies and merchant marine vessels around the world. But of course, it is not the subject of this seminar and I will say no more on diesel engine development today. Gas turbines were used as boost engines along side steam propulsion plant in two classes of vessel introduced into service during that period. Tribal Class Frigates and County Class destroyers. Both used Metropolitan Vickers G6 engines.

In those early days, marine engineers and naval architects were convinced that it would be quite impractical to use lightweight, relatively flimsy aircraft derivative engines. Fortunately, such engines were being introduced into smaller craft such as Motor Torpedo Boats. It was realised that the substantial benefit of building on the investments incurred by aero engine designers in engines that had been subject to substantial development resulted in engines that were compact, reliable, offered high powers and relatively good efficiencies. Today's lightweight, aero derivative gas turbines are used universally in all types of warship from small, fast craft to large carriers.

The next major milestone was the introduction of the aero-based twin spool marine Olympus. First run in Germany on a test bed in 1963 it eventually went to sea in two Finnish corvettes some six months before a prototype propulsion package in the Frigate HMS Exmouth. This had a single Olympus engine and two Proteus cruise engines. These were well proven in smaller craft and in advance of the Tyne engine, which was not yet available. It was this trials ship that finally convinced the United Kingdom to rely on gas turbines as the main propulsion for all future warships.

As an aside, it is interesting to note that the United States with its greater financial and technical resources started a programme of investigating and developing marine gas turbines in 1940. They conducted exhaustive trials and experiments but it was not until 1966, more than a quarter of a century later, that they put their first gas turbine to sea and not until 1975, with the appearance of the SPRUANCE Class destroyer that they first used gas turbines in a major Warship.

Olympus engines went on to power vessels ranging from frigates to carriers and are still found in numbers today. Subsequent engines used by the Royal Navy, and all of which are in use today are the Tyne – used extensively as a cruise engine and the Spey

– another twin spool, simple cycle aero derivative that started test bed running in 1960, went into aero service in 1964 and was first used in warships in the marine version some 15 years later as a boost engine.

So what are we looking for in a marine gas turbine plant?

Naturally it has to be affordable – this is not just the initial purchase but the substantial post procurement support costs.

It has to be minimum weight and space. This is not of course just the propulsion plant. For example, tankage to achieve a desired ship range will clearly vary with propulsion efficiency.

We are looking for the availability of high powers relative to merchant standards. However, the equipment must be capable of long periods at part load since very little time is actually spent at full power. Naturally therefore, part load efficiency is also very important.

Since it is fitted into a warship, it must be capable of operating in an action environment withstanding underwater explosions, blast and action damage.

It must be capable of operating in a salt laden environment, in high sea states and across a wide temperature range.

The system must be flexible enough to allow fast starting, rapid manoeuvring, good endurance and continuous operation at low powers.

It needs high availability with minimum requirement for onboard maintenance.

And to complete the package it should be low noise with a low smoke and Infra red signature.

These requirements are dealt with by providing a fully integrated package drawing on the inherent performance and characteristics of the gas turbine, careful combinations of machinery and the application of supporting ship design features such as shock mounting and integrated intakes and exhausts.

So just how does the marine gas turbine differ from its aero parentage?

When compared to the marine gas turbine engine the military combat aircraft engine is a very much higher rated machine aimed at maximizing the thrust-to-weight ratio. This is achieved through higher pressure ratios and temperatures. For example, modern combat aircraft engine turbine entry temperatures are approaching 2000^0C as opposed to that of the marine Spey which is around 750^0C. As a consequence, overhaul lives of aircraft engines are measured in hundreds of hours as opposed to, for example, 9000 hours for the marine Spey. Hence factors of an order of magnitude are typical.

Due to the differences in usage profile, or throttle modulation, the consumption of component lives governed by low cycle fatigue is again very much greater in a combat engine. It can typically be as much as 50 times higher than for the marine gas turbine.

And, again, reflecting the rating, the levels of reliability for a combat engine tend to be lower than an engine operating in a military marine environment although airworthiness requirements clearly mandate that safety is paramount.

The marine gas turbine has its unique logistic and engineering support problems in that ships often operate many thousands of miles away from "base" for periods of 6 months or more.

The through life support costs of a combat engine can represent up to 40% of the total aircraft platform requirement. This is huge compared with that for a marine gas turbine.

And finally, the marine gas turbine is only one element, albeit an important one, within an overall propulsion system and needs to be considered as such in support terms unlike the fixed wing equivalent.

Because of the continuous demand to optimise performance and reduce costs over the past 30 years we have seen substantial improvements in marine gas turbines with extensions in time between overhauls, major increases in availability and reliability and significant improvements in specific fuel consumption across the power range.

I would now like to turn to the support environment within which we manage the gas turbines of the Royal Navy. In fact the Warship Support Agency provides overarching in service gas turbine support and cooperation through two Memoranda of Understanding involving 4 European nations, 21 years of collaboration and over 3 million shared running hours. The membership of the Olympus and Tyne Memoranda of Understanding, in place since 1980, comprises the United Kingdom, Netherlands, France and Belgium. The Memoranda of Understanding for the Spey was signed in 1989 between the United Kingdom and the Netherlands.

In 1998 the United Kingdom conducted a Strategic Defence Review. It was a foreign policy led initiative to reassess Britain's security interests and defence needs and consider how the roles, missions and capabilities of our Armed Forces and supporting structure should be adjusted to meet the new global strategic realities.

It was needed for four main reasons; UK defence projects were consistently showing time and cost overruns; Defence equipment was becoming increasingly complex and diverse demanding more flexible and shorter acquisition procedures; the threats were less predictable, and recent events certainly highlight this. This demands that new technology needs to be deployed quicker; and finally, defence industry was restructuring demanding that we review our relationship with them.

Ministers agreed that changes were necessary and the strategic defence review government white paper and supporting documents set out the rationale for change and made a number of important recommendations including the setting up of the Defence Logistics Organisation which joined together the three separate logistics support organisations, the Naval Support Command, the Quartermaster General and RAF Logistics Command together with elements of the Assistant Chief of the Defence Staff all under the Chief of Defence Logistics, currently General Sir Sam Cowens.

Now I could bore you all with considerable detail on the Defence Logistics Organisation mission statement, vision, values and so on. You will be relieved to know that I have no intention of doing so. However, it would be remiss of me in the context of this topic not to describe their strategic goal which is to reduce output costs by 20% within 5 years whilst ensuring that the organisation continues to deliver, and where appropriate improve, outputs. This was necessary in order to create the financial headroom to modernise the equipment of the United Kingdom armed forces and to deliver such dramatic reductions in such a short time without crude cuts there was clearly a need to change the way we do business in order to make step changes in performance. It is this emphasis on driving down costs that is central to the strategy and is what I will major on for the remainder of this address.

So what steps have we taken and how are we achieving a change in which we do business. One of the first steps, and arguably one of the most influential was the formation of Integrated Project Teams. I reside in the Warship Support Agency that is an organisation that is responsible for almost every aspect of Fleet support, including material support. It covers everything from running the Naval bases to direct support to the front line. The bringing together of all the elements of warship support is fundamental to achieving the efficiencies being sought by the defence logistics organisation.

The IPTs are at the very core of the Warship Support organisation being directly responsible for the day-to-day support management of the platforms and equipments, in my case propulsion equipment, and are directly accountable to the Chief Executive. As an IPT leader, I am thus empowered to conduct business with a team that has a full range of competencies – technical, commodity management, commercial and contracts and finance. We have been encouraged to challenge accepted practice and seek novel solutions to problems. Clearly, one must be careful to ensure that such solutions are not be at the expense of introducing larger corporate inefficiencies and this is monitored closely. And naturally, when changes introduce clear benefits, IPTs are encouraged to share these new practices with other IPTs.

So what has all this got to do with gas turbines? By way of an example, if one goes back to the organisation as it existed before the Defence Review, one could observe two quite separate organisations responsible for on the one hand technical support, development and post design services and on the other an organisation responsible for the supply of spares and consumables and the repair of equipment returned from the front line. Both groups had separate line management chains and they were housed at geographically separated locations. Now, of course there was communication between the two but there is an enormous difference between this structure and one where both groups are fully collocated and working within the same management group. Not only were communications improved almost beyond recognition but also the much greater understanding of one group by another led to immediate and direct efficiencies and allowed reassessment of working practices and procedures to be conducted much more effectively.

We saw recognition by those responsible for post design work of poor subcomponent reliability that had been masked by routine and regular provision of stores. In house technical expertise was injected into equipment overhaul lines for the first time and we saw logisticians getting early advice on equipment changes which prevented wasted provisioning of obsolete spares. Whilst individually trivial, in total, an organisational shift which reaped and continues to reap substantial benefits and efficiencies.

Another initiative that we have pursued in our aim to drive down the cost of ownership of gas turbines is to study the overhaul of repairable stock or rotables. A team of specialist headquarters staff, together with IPT members – both logisticians and technical, together with storage and transport organisations and industry looked at the total repair loop process. Studies undertaken in the IPT to date in one equipment area have identified significant benefits by improvements in the return and storage system, forecasting and contractor turn round times. In this case, in consultation with the contactor, and at no additional cost to MoD we have reduced average overhaul turn round times by as much as 85%. Of course these sorts of figures will not always be possible but it illustrates that the potential is there. In cost terms one might expect to reduce the overall cost of support in this area by the order of 20%.

Another major initiative was to drive down the volume and value of our stock holdings. Because we have moved away from the management of finances in cash terms alone and moved to Resource Accounting, costs that were never seriously considered before become significant. Interest on capital and the cost of maintenance of capital assets emphasised the need to drive down stock whilst not significantly increasing risk to the front line or the overhaul process. Experience has shown that these reductions can be very significant and I expect reductions of 30 % or more. In the case of the Marine Propulsion IPT these figures are by no means trivial.

The last area that I should like to cover which has made good progress since the formation of Integrated Project Teams is the changing relationship with industry. There is little doubt that we have seen a number of major changes, individually not particularly revolutionary in themselves, but in the climate of change that we now inhabit transform our business relationship. The cornerstone of achieving best value for money in the Ministry of Defence remains competition. But having been through a competition in the equipment area we are seeing a number of changes including much longer term contracts incentivised to deliver continuous improvement through the life of the contract; movement towards prime contracts and, in our case, more comprehensive support arrangements with power by the hour close to reality in some areas of the business. Partnering arrangements have also been pursued trying to change the culture and relationship, developing an environment of openness and trust.

Other areas where significant improvements have been evident are performance monitoring, customer focused business agreements removal of duplication and exchange of information to learn from other areas good practice. Time today does not permit more detail in these areas.

Finally I would just like to say a few words regarding the future of gas turbines in the Royal Navy. One of the trends in recent years in the United Kingdom has been to move towards a prime-contacting environment for the procurement of new equipments. We were concerned that in the marine engineering field such an environment risked development stagnation. There were essentially three reasons for this; the timescales for significant development of new technology were incompatible with platform programmes and the pace of industry led marine engineering development was deemed likely to be too slow; significant departures from known technology represented a degree of risk that future prime contractors were unlikely to be prepared to carry and, unlike most weapons fits, it is very difficult if not impossible to make fundamental changes in the propulsion equipment through the life of the platform such that incremental change is generally not possible. Because of this a marine engineering strategy paper was produced which discussed the best approach to improved propulsion system s for the Royal Navy's future warships due to enter service in the early part of this century. In order to break out of development stagnation it was recommended that some development work was sensible in order to de risk new technologies to the point where a prime contractor would be prepared to take responsibility without an unacceptable risk premium. The paper confirmed that to reduce manpower and running costs Integrated Full Electric Propulsion should be adopted, as should complex cycle gas turbine alternators as an alternative to diesel power generators. The paper was endorsed at board level and confirmed an earlier MoD decision to establish an Electric Ship Programme. Studies indicated that the optimum fit was for three classes of prime mover equipment including high power (21MW), medium power (6-8MW) and anchor load units (1-2MW). Whilst the principle focus was on complex cycle gas turbines, it did not rule out other prime mover options. We are currently looking at a candidate, which meets the requirements of the lowest power option. However, a strong candidate for the high power option was always going to be WR21 Intercooled Recuperated gas turbine the design and development of which began at the behest of the United States Navy on a joint US/UK basis in 1991 with Northrop Grumman as prime contractor and Rolls Royce supplying the RB211 based gas generator and power turbine. This engine is currently undergoing production testing and will first see service in the United Kingdom Type 45 destroyer later this decade. Whether it will see service in the United States in the foreseeable future remains to be seen.

I hope that I have gone some way to setting the scene that we in the United Kingdom marine gas turbine business find ourselves in. The considerable emphasis on cost reduction and continuous improvement is entirely in keeping with the environment that we are faced with.

I for one look forward to an interesting and stimulating seminar and I trust that you will all find the next three days rewarding.

Ladies and gentlemen, thank you for your patience.